Image Deformation Based ABSINTHE

E. Pierre[1,2], N. Seiberlich[3], V. Gulani[4], P. Bourgeat[2], O. Salvado[2], and M. Griswold[3]
[1]Biomedical Engineering, Case Western Reserve University, Cleveland, Ohio, United States, [2]ICT Centre, CSIRO, Brisbane, QLD, Australia, [3]Radiology, Case Western Reserve University, Cleveland, Ohio, United States, [4]Radiology, Case Western Reserve University, Cleveland, United States

Introduction: The previously proposed Atlas Based Sparsification of Image aNd Theoretical Estimation (ABSINTHE) method accelerates acquisition by using an a priori multicoil signal database to identify and remove matching aliased voxels from a parallel imaging acquisition signal thereby making the signal sparser and therefore easier to reconstruct[1] . The performance of the ABSINTHE method is dependent on its ability to extract the best approximation of the object under investigation from the training set. However, variations in coil configuration and sensitivity between the object and the database severely limit the applicability of the method. In order to overcome this limitation, we propose a new ABSINTHE reconstruction scheme which can use any MR image in its training set, regardless of the coil configuration. More importantly, this method allows for preprocessing steps such as bias field correction and image registration of images in the training set. In this method, the coil sensitivity profiles are estimated from the auto calibration set (ACS) lines. Following this estimation, the training data set is registered to this first reconstruction of the image, thereby enhancing the number of relevant images in the training data set. This new ABSINTHE method, known as image deformation based ABSINTHE, is shown to greatly improve the fidelity of the approximation to the object to image, yielding even sparser signal and better reconstruction.

Theory: The image deformation based ABSINTHE follows the same reconstruction method as decribed in [1], but the training set is obtained after several preprocessing steps. First a fully-sampled (FS) but low resolution estimate of the multi-coil image is obtained from the ACS lines, with application of a Hanning window to prevent Gibbs ringing. Using the adaptive method to reconstruct phased array signal[2], we obtain an estimate of the coil sensitivity profiles from this low resolution estimate. A first FS high resolution estimate of the image is obtained by reconstructing the under-sampled (US) k-space signal with GRAPPA[3]. Using the Demons Registration algorithm in ITK, MR images from a previously acquired database are all non rigidly registered to the high resolution GRAPPA estimate. By transforming these registered images in the Fourier domain, and inverse Fourier transforming the signal corresponding to the ACS lines after applying a Hanning window, we obtain a low resolution version of the registered images. For each of these images, we divide them by the initial low resolution estimate of the object, which yields a bias field correction estimation map that we multiply element-wise with the high resolution registered image. This step yields new registered images with apparent intensity inhomogeneities closer to the object to reconstruct. We then simulate the acquisition of these registered images using the estimated coil sensitivity maps, thus finally obtaining a k-space training set of images registered to a first estimate of the object, with similar coil configuration and intensity inhomogeneities. We can then perform a PCA decomposition of the training set in order to perform the reconstruction algorithm described in [1].

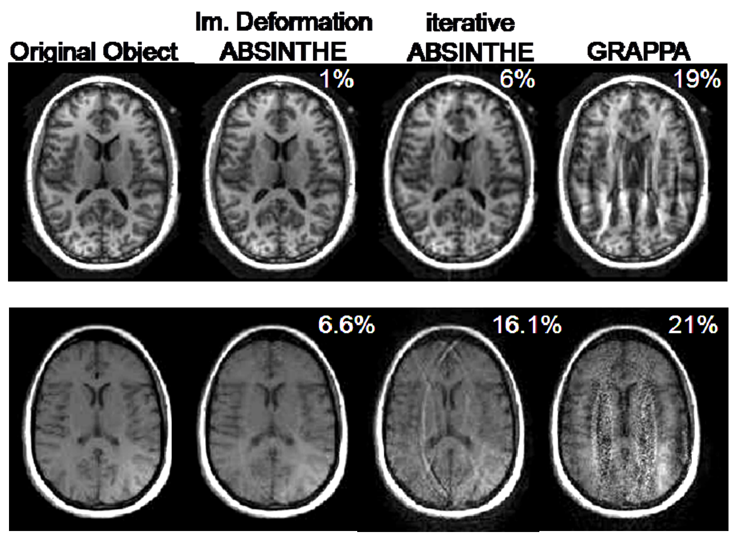

Figure 1: Simulated (top) and in vivo (bottom) computations of the original image (left) for im. deformation ABSINTHE (2nd column), iterative ABSINTHE (3rd column), and GRAPPA (right). The artifact powers (%) for the reconstructions are shown as insets.

Methods: A database of images was first assembled in Matlab from 100 T1-weighted central slice images provided by the Open Access Series of Imaging Studies (OASIS). A 101st brain was selected, a k-space was simulated using a numerical 12-channel coil, undersampled by a factor of R=8, and reconstructed using GRAPPA, iterative ABSINTHE and the image deformation based ABSINTHE, as described above. The artifact powers were calculated relative to the original fully-sampled image. Additionally, to test this new method with in-vivo data, a head volume was acquired using a standard 12 channel head coil on a 1.5T Siemens Avanto scanner (Siemens Medical Solutions, Erlangen, Germany), using a standard T1-weighted Spin Echo sequence (TR=500ms TE=9.5ms 2 avg, Slice=5mm, 19 slices, 5mm x 0.3 gap). A central slice from the brain was then selected to perform a retrospective simulation, undersampled by a factor of R=6. The training set was comprised of similar slices selected from 34 other brains acquired with similar contrast to guarantee proper image registration in ITK. The three different reconstruction methods where then compared with the same metric.

Results: The results from the simulations are shown in Fig. 1. For the first simulation (top row), the artifact power is significantly reduced in the R=8 image-deformation-based ABSINTHE image (1%) compared with GRAPPA (19%) and iterative ABSINTHE (6%). Fig. 1 also shows the results of the in-vivo study, where the artifact power is again significantly reduced in the R=6 image-deformation-based ABSINTHE image (6.6%), compared with GRAPPA (21%), and iterative ABSINTHE (16%).

Discussion: In addition to no longer requiring different databases for each coil configuration, the image-deformation -based ABSINTHE method shows significant improvement in image reconstruction quality over GRAPPA and iterative ABSINTHE. This is due to the increased amount of information in the database which overlaps with the undersampled image to reconstruct, both due to quantity (increased number of images available in the training set) and in quality (images are registered to an estimate of the object). This improved database leads to sparser images and therefore improved GRAPPA reconstruction, even at very high reduction factors.

References : [1] Pierre EY, et al. ISMRM 2010; abstract 2875 : “iterative ABSINTHE” [2] Walsh DO, et al.. MRM 2000; 43: 682–690.
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Acknowledgements : The OASIS database. This study was partially funded by Siemens Healthcare.